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Student's Perception Towards Endodontic Training with Artificial Teeth: What Has Changed?

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ABSTRACT

Objective: This study assessed students' perceptions of artificial teeth (AT) after completing the Endodontics I, II, and III curricular units at the Faculty of Health Sciences, Fernando Pessoa University, Porto, Portugal. Additionally, the study aims to review existing literature on students' perceptions of three-dimensional (3D) printed models used in pre-clinical training, identifying current challenges and future needs for improvement.

Methods: A questionnaire was adapted, consisting of 24 questions, using a 5-point Likert scale, from 1 (Strongly Disagree) to 5 (Strongly Agree), in which students had to compare AT with natural teeth (NT) in various aspects of anatomy and endodontic procedures. For the review of literature, a search was conducted in PubMed, MEDLINE, Scopus, and Web of Science up to March 16, 2025. The search included the keywords: endodontics; natural teeth; artificial teeth; 3D printed teeth; teaching; pre-clinical training and dental education, both individually and in combination using the Boolean operator "AND". Relevant original research studies and review articles, published in English were selected without time restrictions. Additionally, cross-references were examined for further relevant studies.

Results: Overall, students expressed a favorable opinion of AT in relation to external anatomy, radiopacity with files or gutta-percha, ease of acquisition, superior hygiene, and the simplicity of performing endodontic procedures. Conversely, students reported negative perceptions of AT concerning internal anatomy, pulp chamber size, canal shape and size, radiopacity, tactile sensation during access cavity preparation and pulp chamber entry, tactile feedback during endodontic procedures and debris removal, and the adequacy of AT for understanding endodontic techniques.

Conclusion: The incorporation of AT into endodontic training represents a significant advancement toward standardization and improved efficiency in dental education. However, AT cannot fully replicate the tactile feedback and anatomical characteristics of NT. Although AT offers advantages in terms of consistency and availability, their limitations in mimicking the tactile sensation and radiopacity remain critical factors influencing students' perceptions. These findings underscore the need for continued development of AT that more closely mimics the properties of NT.

Keywords: Artificial teeth, dental education, endodontics, pre-clinical training

HIGHLIGHTS

- Artificial teeth represent a significant advancement toward standardization and improved efficiency in dental education.
- Although artificial teeth offer advantages in terms of consistency and availability, their limitations in mimicking the tactile sensation and radiopacity remain critical factors influencing students' perceptions.
- For artificial teeth to truly revolutionize training, it is mandatory that future research must first develop materials with mechanical properties that closely match those of natural teeth, rather than merely presenting alternative models that fall short.

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INTRODUCTION

Endodontics is a key discipline of dentistry, dedicated to the diagnosis, prevention and treatment of pathologies affecting the dental pulp and periradicular tissues. Endodontic success depends on various factors, including canal preparation, disinfection and three-dimensional (3D) obturation (1). In Europe, the European Society of Endodontology provides guidance to dental institutions on structuring their endodontic curricula emphasizing the significance of both pre-clinical and clinical education (2). In the university setting, where students approach endodontics for the first time, pre-clinical practice aims to provide students with the skills necessary to safely and effectively deal with patient treatment (1, 3). Overall technical proficiency in endodontic treatment performed by undergraduate students is generally low, with the risk of incorrect treatments that can lead to iatrogenic errors, such as ledge, perforation, and apical transportation (4). Traditionally, extracted natural teeth (NT) have been used for hands-on practice, but their anatomical variability, that can compromise evaluation standardization, their difficult sterilization and limited availability present significant challenges (3, 5–7). Artificial teeth (AT) have emerged as a solution to these challenges, offering consistent levels of difficulty and accessibility for all students. AT in pre-clinical education has gained ground as a viable alternative for endodontic training (3, 7–10). In the market exists various AT, offering realistic and standardized designs.

Pre-clinical and clinical undergraduate endodontic education programs have been evaluated across different countries (1, 3, 11–14). In a survey across dental schools of the UK, in the pre-clinical setting, 73% of schools used NT, 73% used AT, 60% used canals in acrylic blocks with simple curves, 13% used 3D printed teeth with root canals, and 7% used acrylic blocks with S-shaped curves (11). In Canada the majority of dental programs (70%) used NT and AT, also 40% have introduced 3D printed teeth in their curricula (12). In Italy during preclinical training, students practiced on NT (82.1%), AT (46.4%), canals in acrylic resin blocks with simple curvatures (39.3%), 3D printed teeth with root canals (17.9%), and canals in acrylic resin blocks with S-shaped curvatures (7.1%) across various schools (13). In Spain, all schools (100%) used NT, but also 40% utilized canals in acrylic blocks with simple curves, and 25% used AT (14). Nagendrababu et al. (1) evaluated the current status of endodontic education in dental schools worldwide, 44 universities from 36 countries participated in the survey. From the participating dental schools, 19.4% used only NT, 14% only used AT, 14% used an hybrid approach using NT and AT.

Regarding students' perceptions of AT, most students recognize its advantages- such as fair classification, easy accessibility, reduced cross-infection risks, and anatomical similarity-however, many also express concerns. A common drawback is a different tactile sensation, due to the lower hardness of resins compared to dentine (5, 15). Haptic perception refers to a user's ability to feel tactile sensations or a sense of touch while using a device or instrument (16), in this way the hardness differences between resin and dentine, can hinder the development of proper proprioceptive feedback during canal preparation. Another drawback is the difference of behavior of the resins towards mechanical preparation, leading to a greater accumulation of resin debris more easily causing canal blockages (5). Additionally, differences in radiopacity between AT and NT have been identified as another concern (15).

However, AT normally are associated with high costs, a limited selection of tooth types, and extended delivery times due to reliance on manufacturers. Additionally, there are significant variations in the manufacturing processes and materials used by different commercial brands (9, 17, 18). 3D printing is an advancing technology that has become widely accepted in dentistry. With decreasing costs and an expanding range of materials, 3D printed teeth present new opportunities for creating custom models that are either unavailable on the market or too costly to produce in large quantities. Also, it facilitates enhanced resource sharing and collaborative research efforts among academic and educational institutions (9, 18–20). Nagendrababu et al. (1) reported that 3D printed teeth have already been incorporated into pre-clinical curricula, alongside AT and NT, in 25.1% of the 36 participating dental schools worldwide.

In the pre-clinical curricular units of Endodontics I, II, and III of the Integrated Master's in Dentistry at the Faculty of Health Sciences, Fernando Pessoa University (Porto, Portugal), students are required to undergo pre-clinical endodontic training using both AT (DRSK, Sweden) and NT for anterior and posterior teeth. The AT model (DRSK, Sweden) is specifically designed for practicing all stages of root canal treatment. Each tooth model includes a fully intact crown and roots with a hollow interior replicating the pulp chamber and root canals. To enhance realism, the hollow space is filled with a soft, red-colored resin that mimics the pulp (17).

This study assessed students' perceptions of AT after completing the Endodontics I, II, and III curricular units at the Faculty of Health Sciences, Fernando Pessoa University, Porto, Portugal. Additionally, the study aims to review existing literature on students' perceptions of 3D printed models used in pre-clinical training, identifying current challenges and future needs for improvement.

MATERIALS AND METHODS

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Fernando Pessoa University (FCS/PI 564/24, date 22/04/2024). The questionnaire used in the present study was adapted from a previously validated instrument (21). The adaptation of the questionnaire was conducted by a team comprising three of the study's authors—who are practicing dentists and university professors—and two additional authors who are fifth-year dental students. The primary objective of the adaptation process was to tailor the questionnaire to align precisely with the specific aims of the current study. The adaptation also focused on optimizing the clarity and accessibility of the questionnaire items. Special care was taken to revise technical terms and phrasing to ensure that the language used was appropriate for dental students. The adapted version was then reviewed by all members of the adaptation team to ensure consistency, comprehensibility, and alignment with the study's goals. The questionnaire was introduced in Google Forms, and a QR Code linking to the Google Forms was published on posters around the University Campus between 13 and 17 of May, 2024. The study involved students from the Integrated Master's in Dentistry from the Health Sciences Faculty of Fernando Pessoa University. The inclusion criteria were that the students must have completed Endodontics I, II, and III curricular units, to ensure that students had experience with both AT and NT in pre-clinical endodontic treatment. Consequently, during the questionnaire availability period only fourth- and fifth-year students were eligible to participate, thereby ensuring that all respondents also possessed clinical experience.

The anonymous questionnaire used in the present study consisted of 24 questions, using a 5-point Likert scale, from 1 (Strongly Disagree) to 5 (Strongly Agree), in which students had to compare AT with NT in various aspects of anatomy and endodontic procedures. The main categories evaluated included:

- External and internal anatomy (e.g., shape of the pulp chamber and location of root canals),
- Radiopacity and ability to visualize endodontic instruments or gutta percha on radiographs,
- Tactile sensation during procedures such as drilling and canal shaping,
- Ease of obtaining and hygiene,
- General preference for teeth in practical exams and continuous assessments.

To understand the overall opinion of the students towards AT in comparison with NT, the ranking scale answers were recategorized into three sets/opinions, with values 1 and 2 merged to be considered negative opinions towards AT, while answers with values 4 and 5 were merged and considered positive opinions towards AT. The answers with a ranking value of 3 were considered neutral opinions, meaning that the students considered AT equal to NT in that precise question (17, 22).

Review of Literature

For the review of literature, a search was conducted in PubMed, MEDLINE, Scopus, and Web of Science up to March 16, 2025. The search included the keywords: endodontics; natural teeth; artificial teeth; 3D printed teeth; teaching; pre-clinical training and dental education, both individually and in combination using the Boolean operator "AND". Relevant original research studies and review articles, published in English were selected without time restrictions. Additionally, cross-references were examined for further relevant studies.

Statistical Analysis

Statistical analysis was carried out using SPSS statistics software (Version 29.0, 2022; IBM Corp., Armonk, New York). Data description was performed using absolute and relative counts of the ranking answers, as well as the calculation of the median value and respective interquartile range (the first and third quartiles). Significant differences between results and a hypothetic neutral opinion (no difference towards AT or NT) were calculated through a one-sample Wilcoxon Signed Rank Test. Values $p<0.05$ were considered significantly different.

RESULTS

The responses of 220 students to the questionnaire were analyzed, with the frequency and percentage of each response calculated, also to evaluate the overall student perception of AT compared to NT, responses indicating positive and negative opinions toward AT were examined (Table 1) and illustrated (Fig. 1).

Overall, students expressed a favorable opinion of AT in relation to external anatomy, radiopacity with files or gutta-percha, ease of acquisition, superior hygiene, and the simplicity of performing endodontic procedures. Conversely, students reported negative perceptions of AT concerning internal anatomy, pulp chamber size, canal shape and size, radiopacity, tactile sensation during access cavity preparation and pulp chamber entry, tactile feedback during endodontic procedures and debris removal, and the adequacy of AT for understanding endodontic techniques.

In response to question 24 ("Overall, I preferred working on AT compared to NT"), student opinion was significant and predominantly negative ($p<0.001$). Of the 220 respondents, 113 (51.4%) expressed a negative preference for AT over NT.

DISCUSSION

The results of the present study indicate that students had a positive opinion towards AT, in relation to external anatomy, radiopacity with files or gutta-percha, ease of availability, superior hygiene, and the simplicity of performing endodontic procedures. Conversely, students reported negative perceptions of AT concerning internal anatomy, pulp chamber size, canal shape and size, radiopacity, tactile sensation during access cavity preparation and pulp chamber entry, tactile feedback during endodontic procedures and debris removal, and the adequacy of AT for understanding endodontic techniques. The overall student opinion towards AT was predominantly negative, with a statistically significant difference ($p<0.001$). Of the 220 respondents, 113 (51.4%) expressed a negative preference for AT over NT.

These findings are consistent with existing literature, which indicates that AT are readily available in sufficient quantities without the limitations associated with collecting NT (5, 9, 23), are more hygienic and are easier to handle since they do not require liquid storage (5, 21), and are standardized, ensuring a consistent level of procedural difficulty for all students and enabling fair assessment (5, 6, 9, 15, 19). However, Reymus et al. (9) found that students perceived the preparation of AT to be easier than that of NT, largely due to the difference in hardness. A primary concern regarding AT is the difference in radiopacity and hardness between the resin material and natural dentine, as reported in several studies (9, 15, 18, 23), these findings align with the findings of the present study in which students considered AT to be simpler to perform endodontic procedures and also had a negative opinion towards radiopacity and overall tactile sensation. Regarding radiopacity, the present study yields ambiguous results. While students expressed a negative opinion toward the radiopacity of AT, their views were positive concerning radiographic assessments during working length determination and master cone selection . This discrepancy

TABLE 1. Results of students' responses/opinion (range: 1 (Strongly Disagree) to 5 (Strongly Agree)) of the questionnaire (total n=220) and opinion comparison concerning having a neutral opinion (H0: Median ranking answer = neutral opinion (=3))

		Ranking opinion towards AT						Me ranking (Q1-Q3)	p*
		Negative opinion		Neutral opinion		Positive opinion			
		n	%	n	%	n	%		
1	AT are similar to NT in terms of external anatomy	33	15.0	61	27.7	126	57.3	4 (3–4)	**<0.001**
2	AT are similar to NT in terms of internal anatomy	106	48.2	70	31.8	44	20.0	3 (2–3)	**<0.001**
3	AT are similar to NT in terms of pulp chamber localization	71	32.3	76	34.5	73	33.2	3 (2–4)	0.905
4	AT are similar to NT in terms of the shape of the pulp chamber	73	33.2	79	35.9	68	30.9	3 (2–4)	0.393
5	AT are similar to NT in terms of pulp chamber size	85	38.6	73	33.2	62	28.2	3 (2–4)	**0.019**
6	AT are similar to NT in terms of root canal location	78	35.4	78	35.5	64	29.1	3 (2–4)	0.051
7	AT are similar to NT in terms of the shape of the root canals	86	39.1	84	38.2	50	22.7	3 (2–3)	**<0.001**
8	AT are similar to NT in terms of the size of the root canals	79	36.0	85	38.6	56	25.5	3 (2–4)	**0.002**
9	AT are similar to NT in terms of radiopacity	85	38.7	71	32.3	64	29.1	3 (2–4)	**0.028**
10	AT are similar to NT in terms of the sensation of drilling with a turbine and a drill during the access cavity.	122	55.5	57	25.9	41	18.6	2 (1–3)	**<0.001**
11	AT are similar to NT in terms of the sensation of falling when they reach the pulp chamber	95	43.2	69	31.4	56	25.4	3 (2–4)	**<0.001**
12	AT are similar to NT in terms of the resistance of root canal walls during instrumentation.	113	51.4	60	27.3	47	21.4	2 (2–3)	**<0.001**
13	AT are similar to NT in terms of the tactile feel of the files during instrumentation	108	49.1	74	33.6	38	17.3	3 (2–3)	**<0.001**
14	AT are similar to NT when it comes to removing debris formed during instrumentation and irrigation.	111	50.5	70	31.8	39	17.7	2 (2–3)	**<0.001**
15	AT are similar to NT in terms of the visibility of the files on working length determination radiographs and the difficulty in determining the working length.	55	25.0	65	29.5	100	45.4	3 (2.25–4)	**0.003**
16	AT are similar to NT in terms of the visibility of guttapercha cones on master cone selection radiographs and the difficulty in properly assessing the position of the guttapercha cone in relation to the apex	48	21.9	74	33.6	98	44.5	3 (3–4)	**<0.001**
17	AT are easier to obtain than NT	39	17.7	56	25.5	125	56.8	4 (3–5)	**<0.001**
18	AT are more Hygienic compared to NT	29	13.2	52	23.6	139	63.2	4 (3–5)	**<0.001**
19	AT are more suitable for understanding how to carry out non-surgical endodontic treatment compared to NT	86	39.1	74	33.6	60	27.2	3 (2–4)	**0.025**
20	AT are more suitable for Endodontics laboratory classes than NT	87	39.6	67	30.5	66	30.0	3 (2–4)	0.066
21	AT are fairer for the continuous assessment process than NT	66	30.0	68	30.9	86	39.1	3 (2–4)	0.102
22	AT are more suitable for practical examinations than NT	75	34.0	65	29.5	80	36.3	3 (2–4)	0.941
23	AT are simpler to perform endodontic procedures on than NT	43	19.6	62	28.2	115	52.3	4 (3–5)	**<0.001**
24	Overall, I preferred working on AT compared to NT	113	51.4	56	25.5	51	23.1	2 (1–3)	**<0.001**

*: Wilcoxon signed rank test. AT: Artificial teeth, Me: Median of the ranking observations, Q1: First quartile of the ranking observations, Q3: Third quartile of the ranking observations, NT: Natural teeth

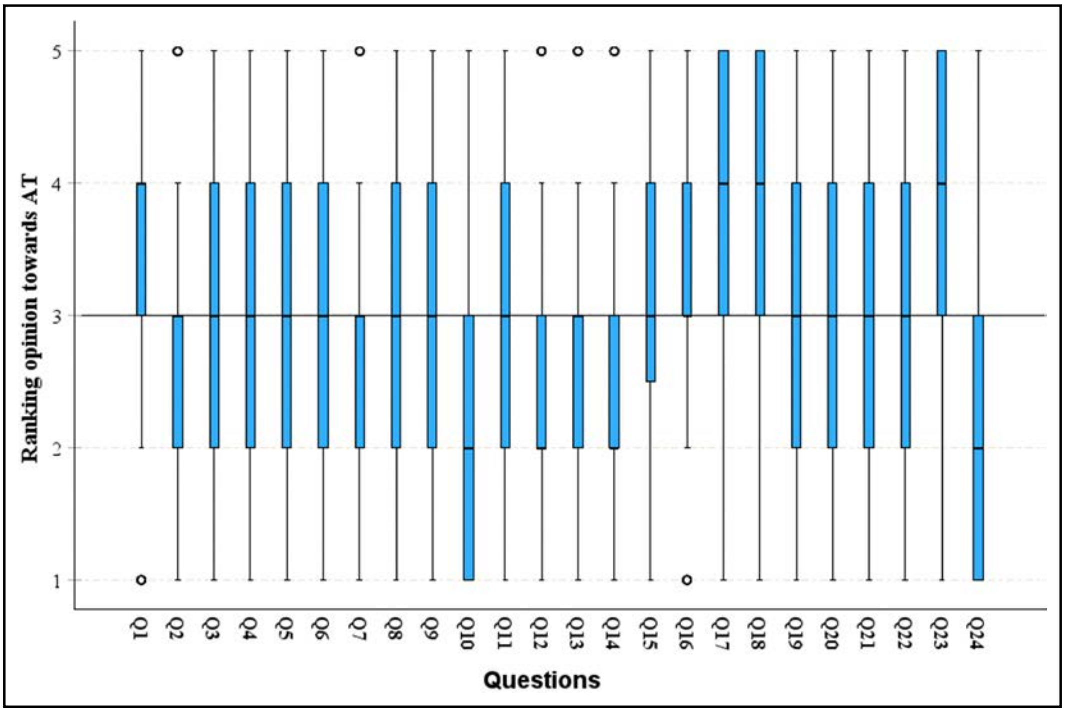

Figure 1. Results of student's opinion (Ranking opinion towards AT (artificial teeth), ranging from 1 (Strongly Disagree) to 5 (Strongly Agree)) from the questionnaire (Q1 to Q24 corresponds to the 24 questions). The central blue box represents the interquartile range (IQR), containing the observed opinion values ranked between the 1st and 3rd quartiles regarding AT. The thicker line within the box indicates the median opinion value. The lines extending above and below the box (whiskers) represent the expected range of observations, while the dot outside these lines corresponds to an outlier — a value that deviates significantly from the other participants' responses

may be attributed to differences in how the X-rays are conducted during pre-clinical training with AT and NT. Initial X-rays of both AT and NT are taken with the tooth alone. During working length determination and master cone selection X-rays, NT are embedded in light-cured acrylic. However, due to the heat produced by the light source during the polymerization, AT are embedded in dental wax (24). These differences in embedding materials could influence how students perceive radiopacity (25). Regarding the debris removal, students had a negative opinion, since sticky debris generated during root canal shaping obstructs the canals, making irrigation difficult (17). In the present study, the overall student opinion towards AT was predominantly negative, this aligns with the findings of a systematic review of the literature that stated most students strongly preferred working with NT over AT due to the inadequate physical properties of the AT tested (8).

Nonetheless, a study by Tchorz et al. (10) compared the impact of training with AT versus NT on the quality of students' first patient-performed root canal treatments, providing insights into the efficacy of each training method and found no significant differences between students trained with AT and those trained with NT in the quality of their first patient-performed root canal treatments (10). However, the preference for a hybrid model highlights the need for balance between standardization and realistic tactile feedback.

The primary limitation of the present study is its exclusive focus on student perceptions within a single institution, which consequently confined the evaluation to the AT provided by DRSK (Sweden) and the specific endodontic preparation protocol taught at that institution. This restricts the generalizability of the findings, as it remains unclear whether students' perceptions would be similar if AT from other manufacturers, or different preparation protocols were used. It is well established that AT varies in materials, design, and anatomical features, all of which can influence perceived realism, tactile feedback, and the overall quality of training.

To overcome the limitations associated with commercial AT, several studies have proposed new models for endodontic education, leveraging the advantages of 3D printing technology.

Reymus et al. (20) developed an interdisciplinary teaching model that simulates various treatment procedures using 3D printing with a Digital Light Processing (DLP) printer. However, students criticized the model for its limited radiopacity and reduced hardness.

Kolling et al. (21), investigated student acceptance and the educational benefits of an individualized 3D printed tooth model versus traditional methods using NT and resin blocks, in a preclinical endodontic course. Students did not prefer working with 3D printed teeth compared to NT. The majority of responses leaned toward the negative side, with the soft material properties and low radiopacity being the most frequently cited concerns. NT received higher ratings for three key aspects: "enthusiasm to learn and master root canal treatment", "acquisition of fine motor skills," and "facilitation of spatial awareness".

Tsai et al. (22) developed a teaching model consisting of a replaceable tooth and a model base, both fabricated using a DLP printer. The crown was printed using AA Temp resin (Enlighten Materials, Taipei, Taiwan) mixed with 8% barium sulfate, while the root was made from DD Guide resin (Enlighten Materials) mixed with 10% barium sulfate. To evaluate students' perceptions of the new training system, a questionnaire was administered to assess their satisfaction with the 3D printed teeth and model base. The results indicated that most students favored the new system, with nearly all questionnaire items receiving a satisfaction rate of 80% or higher. However, concerns were raised regarding the hardness and tactile sensation of the 3D printed teeth, and student opinions on their radiopacity were inconsistent.

Meglioli et al. (26) produced replicas of teeth, replicating both internal and external anatomy using standard triangle language (STL) files. These replicas were printed with a vat photopolymerization 3D printer using Model V2 resin. All students found the resin to be softer than natural dentine, and 79% reported that the 3D printed teeth did not provide a realistic tactile sensation during preparation.

Göksu et al. (27) evaluated the effectiveness of 3D printed dental models in practical endodontic training. Using cone beam computed tomography scans of a human mandibular first molar, the data were converted into STL format to produce 3D printed tooth models. Two different 3D printing techniques, stereolithography and fused deposition modeling were used to fabricate various model components. Different resins were used to create the alveolar part, teeth, and carious lesions, while the pulp was simulated using an impression material. Students found the models effective in replicating anatomical characteristics, but the reproduction of hard tissue properties was identified as the weakest aspect. When asked about the hardness of the 3D printed teeth compared to NT, 45.2% of respondents selected "I do not approve," making it the most common response.

Kadrija et al. (28) evaluated the efficacy of a 3D printed training kit for preparing endodontic access cavities in calcified teeth by undergraduate students and dentists. A micro-CT scan of a premolar's root canal system was digitally modified to design an endodontic training kit comprising 10 teeth, each representing a progressively increasing degree of pulp canal calcification. Three copies of a tooth model with a medium calcification level (5/10) were fabricated in opaque resin, while an additional set of 10 transparent teeth featuring red-colored pulp was produced using PolyJet 3D printing. The transparency of these models allowed for controlled training in access cavity preparation. In the study, 27 undergraduate students and 10 dentists each performed 13 access cavity preparations (one before training and two after training), with CBCT used to quantify substance loss and a questionnaire to assess user satisfaction. In this study, student opinions were divided regarding whether the printed teeth were harder or softer than NT, with most students noting that the printed models did not accurately replicate the feel of extracted teeth. In contrast, the dentists consistently observed that the 3D printed teeth were either comparable to or softer than NT.

The reviewed literature suggests that, in student's perception, 3D printed teeth currently share with AT, similar drawbacks regarding tactile sensation and radiopacity. Nevertheless, as previously discussed, 3D-printed teeth possess the potential to address and surpass several of the inherent limitations associated with commercially available AT.

NT have exceptional mechanical properties that are still challenging to replicate through engineering methods. Although current AT successfully mimic the shape and color of NT, they are typically crafted from materials that show considerable mechanical differences from NT. Accurately replicating both the morphological features and the mechanical properties of NT remains a critical challenge and is arguably the most important requirement in the development of realistic dental models. This task is particularly difficult due to the complex interplay between tooth morphology, material composition, and structural organization (29).

To overcome this challenge, ceramic AT made from hydroxyapatite have been developed (30). However, a major issue persists in terms of tactile sensation, as hydroxyapatite alone cannot replicate all the components of NT. Despite these advancements, ideal materials for 3D printed teeth are still lacking. It is believed that enhancing the physical properties of printed replicas could be achieved by increasing the filler content in the resin and improving the resin-filler interface (22).

Another rapidly growing field is 3D bioprinting, which enables the efficient fabrication of complex, biologically relevant structures incorporating cells or bioactive molecules. This technology replicates native tissue architecture and is highly valuable in regenerative medicine and tissue engineering. Collagen-based scaffolds, widely used in wound healing, nerve regeneration, and orthopedic procedures, are often modified with polymers or enhanced with ceramics such as hydroxyapatite to improve mechanical strength. Composites combining collagen and hydroxyapatite are particularly used for bone regeneration (31). However, further research is needed to determine whether the inclusion of collagen in combination with hydroxyapatite can produce a material that mimics the structural and mechanical properties of natural dentine.

Another important concern is the limited capability of current 3D printing technology to accurately reproduce complex internal dental anatomies. This includes fine structures such as lateral canals and narrow isthmuses (9). Nonetheless, recent studies about ultra-resolution microprinting with an optical resolution of 1μm (32) with the capacity of printing with multi-materials (33), suggest promising potential for the future fabrication of internal anatomically accurate 3D printed teeth. Nonetheless, it is important to recognize that for 3D printed teeth to be a practical and viable solution, the printing process must be scalable, time-efficient, and cost-effective (7).

In conclusion, the integration of AT, particularly those created through 3D printing, into pre-clinical endodontic education shows great promise, however little to nothing has changed since early studies with AT. A multitude of articles have introduced new models only to reach the same conclusion: the necessity to mimic NT's tactile properties and radiopacity. For AT or 3D printed teeth to truly revolutionize training, it is mandatory that future research must first develop materials with mechanical properties that closely match those of NT, rather than merely presenting alternative models that fall short. As dental education evolves, continuous advancements in 3D printing technology with consequently more realistic 3D printed teeth, will be crucial for establishing training protocols that effectively prepare students for real-world clinical challenges.

CONCLUSION

The incorporation of AT into endodontic training represents a significant advancement toward standardization and improved efficiency in dental education. However, AT cannot fully replicate the tactile feedback and anatomical characteristics of NT. Although AT offers advantages in terms of consistency and availability, their limitations in mimicking the tactile sensation and radiopacity remain critical factors influencing students' perceptions. To enhance the effectiveness of AT in endodontic training, the development of materials that closely simulate the physical properties of dentine is mandatory.

Disclosures

Ethics Committee Approval: The study was approved by the Fernando Pessoa University Ethics Committee (no: FCS/PI 564/24, date: 22/04/2024).

Informed Consent: Informed consent was obtained from all participants.

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